THE EFFECTS OF METHANE GAS PRESSURE ON OPTICAL AND ELECTRICAL PROPERTIES OF NITROGENATED CAMPHORIC CARBON THIN FILMS GROWN BY SURFACE WAVE MICROWAVE PLASMA CHEMICAL VAPOR DEPOSITION

M. Rusop, T. Soga and T. Jimbo

Department of Environmental Technology and Urban Planning,

Nagoya Institute of Technology, Gokiso-cho, Showa-ku, Nagoya 466-8555, Japan

S. Adhikari, A.M.M. Omer, S. Adhikary, H. Uchida and M. Umeno

Department of Electronic Engineering, Faculty of Engineering,

Chubu University, Matsumoto-cho1200, Kasugai 487-8501, Japan

Keywords: a-C:N; camphoric carbon; optical gap; surface wave; microwave CVD.

Abstract

We have studied the influence of the methane gas (CH_4) pressure on the bonding, structural, optical and electrical properties of the nitrogen doped amorphous carbon nitride (a-C:N) thin films grown by newly developed Surface Wave Microwave Plasma Chemical Vapor Deposition (SWMP-CVD) on quartz and silicon (100) substrates. The a-C:N films are deposited with varying CH_4 partial gas pressure in range from 5 to 20 ml/min. To incorporate nitrogen in the a-C:N film, we have introduced nitrogen gas (N) at 5 ml/min partial gas pressure in the chamber. The effects of the CH_4 gas pressure on the surface morphology, composition, structure, optical and electrical properties of the N incorporated camphoric carbon thin films have been investigated using Scanning electron microscopy (SEM), Atomic force microscopy (AFM), Auger electron spectroscopy (AES), UV-Visible spectroscopy and Four-point probe resistance measurement. We have succeeded to grow a-C:N thin films using SWMP-CVD at room temperature and found that the amorphous structure of a-C:N films can be changed and is strongly dependent on the CH_4 gas source.

RESULTS AND DISCUSSIONS

Recently, a new deposition method (Fig. 1), namely Surface Wave Microwave Plasma Chemical Vapor Deposition (SWMP-CVD) has been developed [1,2]. This deposition technique is a new deposition method of carbon thin films without corroding ions on substrate. It is also noticed as one of promising plasma sources for the large area thin film deposition. Since structural, physical and optical properties of a-C thin films grown by SWP-CVD for solar cell application are not yet understood, in this paper, we report our latest result on the properties of nitrogen doped amorphous carbon nitride (a-C:N) thin films.

The optical properties was characterized by studying the optical transmittance and reflectance spectra of the films using UV|VIS|NIR spectrometer - Jasco V570. The optical absorption spectra of the films were obtained from optical transmittance and reflectance measurements in the range of 200 to 2500 nm.

From the measurements of optical transmittance and reflectance in range of 300 to 1150 nm wavelength (about 1 to 4 eV photon energy), an optical absorption coefficient (α) on the order of $10^3 – 10^4$ cm^{-1} is obtained for the undoped a-C. The α has increase with increased up to $10^3 – 10^4$ cm-1 for a-C:N films grown at 5 ml/min of CH_4 gas. The α is almost unchanged with higher CH_4 gas up to 20 ml/min. The high absorption in the power-law (Tauc) and exponential (Urbach) region is ascribed to the presence of more graphitic component (sp^2- bonds) in the carbon film. The optical absorption spectra in this experiment have a similar shape to the absorption spectra reported by Puretzky et al. [3].

As shown in figure 2, the optical gap (E_g) is obtained from the extrapolation of the linear part of the curve at the absorption coefficient α = 0 using the Tauc relation [4], $(\alpha hv)^{1/2} = B(E_g\text{-}hv)$, where, B is the Tauc parameter. The estimated E_g for undoped a-C films A is approximately 2.3 eV and decreased up to approximately 2.1 eV with increased of CH_4 gas at 5 ml/min. Our result shows the E_g is almost constant at 2.1 eV, indicates there is no micro-structural disorder with higher CH_4 gas up to 20 ml/min.

The electrical resistivity (ρ) was measured at RT by a 4-point probe resistance measurement method, the usual way for high resistance measurement. The ρ values for each film were the average of measurements made at different positions on the film surface. The ρ values of Sample A was measured to be around 6.2 x 10^5 (Ω-cm), is higher compared with the ρ = 5 x 10^4 (Ω-cm) values of a-C:N film grown at 5 ml/min CH_4 gas. The ρ of a-C:N films decrease with higher CH_4 gas up to 8 x 10^3 (Ω-cm), 4 x 10^3 (Ω-cm) and 1 x 10^3 (Ω-cm) respectively.

Details of the experimental results and discussions will be presented during the conference presentation.

Conclusions

We have successfully grown nitrogen doped amorphous carbon (a-C:N) thin films by newly developed surface wave microwave chemical vapor deposition (SWP-CVD) at 5 ml/min N_2 gas ambient with the CH_4 precursor gas from 5 to 20 ml/min. The dependence of the CH_4 gas ambient on the surface morphology, composition, structure, optical and electrical properties of the films was investigated. It is found that the amorphous structure of a-C:N films can be changed by CH_4 gas and the a-C:N films grown at higher CH_4 gas have relatively high electrical conductivity.

REFERENCES

1. M. Nagatsu, T. Sane, N. Takada, W.X. Guang, T. Hirao and H. Sugai, Jpn. J. Appl. Phys. Vol. 39, pages 929 (2000).
2. M. Nagatsu, T. Sano, N. Takada, N. Toyoda, M. Tanga and H. Sugai, Diamond Relat. Mater. Vol. 11, pages 976 (2002).
3. A.A. Puretzky, D.B. Geohegan, G.E. Jellison Jr. and M.M. Mc Gibbon in: H.A. Atwater, J.T. Dickinson, D.H. Lowndes and A. Polman (Eds.), Film Synthesis and Growth Using Energetic Beams, San Francisco, U.S.A., April 17-21, 1995, Materials Research Society Symposium Proceeding Vol. 388 pages 145 (1995).
4. J. Tauc: Amorphous and Liquid Semiconductors (Plenum Press, London, New York, 1974) Chap. 4.

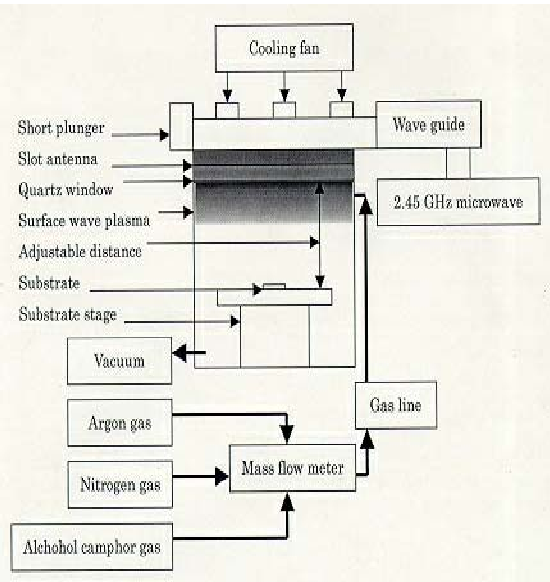

Figure 1: Image of newly developed Surface Wave Microwave Plasma Chemical Vapor Deposition (SWMP-CVD) System.

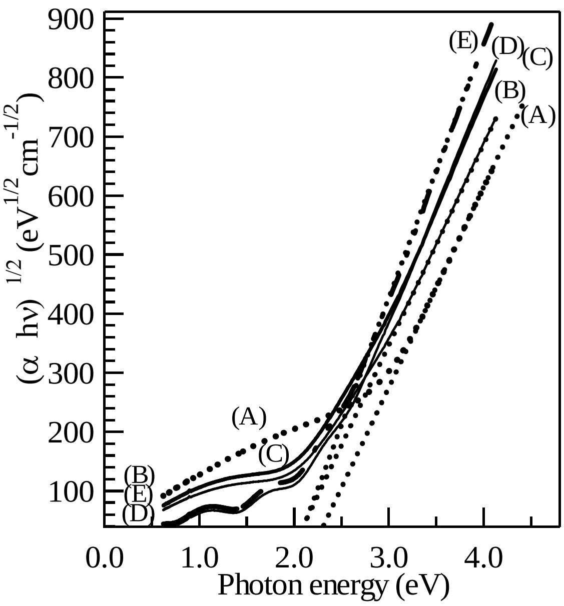

Figure 2: Tauc plot of $(\alpha h\nu)^{1/2}$ as a function of photon energy (hv), for (A) undoped a-C, and a-C:N films grown at (B) 5, (C) 10, (D) 15, and (E) 20 ml/min of CH_4 gas source.